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THE
ONTARIO WATER RESOURCES
COMMISSION

INVESTIGATIONS OF FOG CONDITIONS

in the

COPPER CLIFF AREA

JUNE, 1968



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A REPORT
on
INVESTIGATIONS OF FOG CONDITIONS
IN THE COPPER CLIFF AREA
COPPER CLIFF
DISTRICT OF SUDBURY

June 3-5, 1968

by
Division of Industrial Wastes
ONTARIO WATER RESOURCES COMMISSION

INVESTIGATIONS OF FOG CONDITIONS IN THE COPPER CLIFF AREA

An investigation into the periodic fog conditions in the Copper Cliff area was conducted by the Division of Industrial Wastes because this problem has been attributed in part to the discharge of industrial effluents to Copper Cliff Creek. This study was undertaken to determine the factors involved and what remedial measures might be adopted.

SUMMARY

It is an established fact that intermittent occurrences of fog do occur in the vicinity of Highway 17 and Copper Cliff Creek when they do not occur in neighbouring areas.

Some individuals and groups feel that this fog condition is contributing to the frequency of highway traffic accidents in the area and have requested that "the Provincial Government (presumably the OWRC) shall undertake an immediate study of our allegations of pollution being the cause of this fog and its attendant unnatural financial hardships and tragedies". This is quoted from a resolution presented to the Ontario Water Resources Commission on May 16, 1968, and endorsed by approximately ten municipalities in the area.

Factors affecting the formation of the fog include climatic conditions, the proximity of the creek to the highway, the fact that the area is a natural depression, and the temperature of the water in Copper Cliff Creek. Data presented in the report show that the waste discharges to the Creek do result in a temperature rise in the Creek and thus could contribute to the localized fog conditions. However, it is not possible to determine to what extent this higher temperature contributes to the probability of fog formation.

As there are a number of factors to be considered, it is difficult to determine whether any one factor has a greater effect than the others. However, local concern for the fog occurrences is sufficient to warrant the consideration of corrective action.

Suggested measures designed to eliminate or reduce the probability of fog formation include cooling of the waste discharges, covering of the Creek or diversion of the Creek. It is recommended that a meeting of all those concerned or involved be held to determine the course of action to be adopted

Description of the Area

A sketch map of the vicinity is presented in Figure 1. Copper Cliff Creek drains into Lady MacDonald Lake, located to the northwest of Copper Cliff, and acts as the receiving stream for:

1. the decant from The International Nickel Company's tailings disposal area,
2. wastewater from The International Nickel Company's copper refinery,
3. wastewater from The International Nickel Company's smelter,
4. wastewater from Canadian Industries Limited's liquid sulphur dioxide plant, and
5. treated sewage from the Copper Cliff sewage treatment plant.

Copper Cliff Creek flows in an easterly direction between Highway No.17 and The International Nickel Company's smelter in Copper Cliff and after receiving the waste effluents from the smelter, the sulphur dioxide plant and the sewage treatment plant, flows under the slag car railway line and continues eastward for approximately one quarter mile. It then flows under Highway No. 17 to the south

side and continues eastward roughly parallel to the Highway for approximately three quarters of a mile before turning south at Kelly Lake Road. East of the slag car railway overpass, there is a natural dip in the terrain with the low point at or in the area where the creek crosses the highway.

The fog conditions on Highway No. 17 have been reported to exist most frequently between the general vicinity of the railroad overpass and the sewage treatment plant on the west and the vicinity of Kelly Lake Road to the east.

Fog Formation

A report entitled "An Analysis of Local Fog in the Copper Cliff Area" prepared by the Meteorological Branch of the Federal Department of Transport some years ago before the widening of Highway No. 17, outlined the mechanism of fog formation as follows:

"The cooling of air in the lower levels of the atmosphere to its dew point results in the condensation of suspended water vapour and hence the formation of fog. "Radiation fog" is a result of the cooling of the ground at night being communicated to the air. The air must contain sufficient moisture to permit condensation and since the cooling is not usually great, the relative humidity must be in the order of 80% when there is an abundance of condensation nuclei such as smoke particles to aid the fog formation. Radiation fog is very local, since the cooled air tends to drain into low areas; it generally burns off during the morning. Steam fog is formed by cool air moving over warmer water; water vapour escaping from the water surface saturates the colder air."

The report noted that from the topography of the area, the site was a natural bowl for radiation and steam fog.

A graph of air temperature, approximate creek temperature and dew point for a one-year period was also presented and is reproduced in this report as Figure 2. According to the report, localized fog conditions were limited to the approximate period from November to May since the dew point and the air temperature were closest during this period, giving maximum probability of the dew point being equal to the air temperature.

Occurrence of Fog Conditions

Table I presents a summary of fog reports made by patrolmen of the Department of Highways for the winters of 1965-66 and 1967-68. The fog reports for the winter season of 1967-68 were made at the request of the Air Pollution Control Service of the Department of Health. The data indicates that the localized fog conditions occurred generally between December and March.

Traffic Accidents

Table II presents a summary of the automobile accidents that have occurred on Highway No. 17 within the Corporate Limits of the Town of Copper Cliff.

Field Investigation

On June 3, 4 and 5, 1968, a field investigation was undertaken to determine the existence of any temperature differentials in Copper Cliff Creek upstream and downstream of the wastewater discharges from the smelter, sulphur dioxide plant and the sewage treatment plant. While it is recognized that the absolute values of the temperatures existing in the creek will vary widely during the year, the establishment of the existence of any temperature differentials was felt to be possible at any time of the year.

The field results are tabulated in Table III of this report. Averaged results for sampling periods 2-6 are presented graphically in Figure 3. Sampling periods 1, 7 and 8 were not included in the average because at those times, temperature readings were not obtained at all the points. The resulting plot presents an average temperature profile of the creek for June 3 and 4, 1968.

Samples of the waste discharges to the creek have been taken for chemical and biochemical analysis on numerous occasions in the past. A summary of the results for 1966 and 1967 is presented in Table IV. Flow data are presented in Table V.

Discussion of Results

Based on the chemical and biochemical analytical results reported in Table IV, it is not believed possible for chemical or biochemical impairment of the creek to be responsible for the generation of fog. Dissolved solids lower the vapour pressure of water, and therefore, would theoretically lower the amount of water vapour rising from the stream. Dissolved solids also lower the freezing point of water and could be a factor in preventing the formation of an ice cover on the stream. Acids such as sulphuric acid fume at very high strengths. However, the concentration of acidic material in the creek is much too dilute to be considered a cause for the fog or hazy conditions reported in the vicinity.

Referring to Figure 3 and the tabulated temperature data in Table III, a marked temperature gradient across the creek was observed from the point of entry of the smelter waste discharge downstream to the railway overpass. Further downstream, at the point where the creek crossed the highway, thermal mixing had apparently been achieved since the temperatures near the two banks were identical or approximately identical.

The average temperature of the creek upstream of the smelter waste effluent discharge was 68.5°F. The average smelter effluent temperature was 76.8°F. Downstream of the smelter, the temperature of the creek had risen to 72.8°F on the north side of the creek. A very small temperature rise of about 0.5°F was observed on the south side.

The effluent discharged from the Canadian Industries Limited plant had an average temperature of 72.6°F, also warmer than the average stream temperature. However, the volume of wastewater from this source was relatively small (approximately 50,000 gpd) and a temperature rise downstream was not observed. Downstream of C-I-L's discharge the creek near the north bank had a temperature of 71.6°F, lower than upstream of C-I-L's effluent, while the temperature near the south bank rose to 70.8°F. Part of this rise would be due to mixing.

The average temperature of the sewage treatment plant effluent at 64.8°F, was cooler than that of the stream. The sampling point at the railroad culvert downstream of the sewage treatment plant was very close to the discharge. Therefore, very little mixing would have been achieved between the discharge and this sampling point. The average temperature near the north bank dropped very slightly, while the average temperature drop near the south bank was 5.5°F. At the highway culvert, the average temperatures obtained were 71.4 and 71.2 degrees Fahrenheit near the east and west banks respectively, indicating good mixing had been achieved at this point. The total rise in temperature as the creek flowed past the three discharges was 2.8°F. At the bend in the creek and at the mouth of the creek, the average temperatures obtained were 71.8°F.

During the winter months, stream temperatures would, of course, drop significantly. The waste effluent temperatures would also drop appreciably but

probably not to the same extent. The temperatures of the waste discharges from industrial sources would, in all probability, remain higher than that of the stream. The effluent from the sewage treatment plant could be expected to be in the order of 40°F or higher, also warmer than that of the stream at that time.

Table V presents flow data and shows that the volume of water contributed by Canadian Industries Limited was almost negligible. The volume contributed by the smelter was in the order of 6% of the total flow and the volume contributed by the sewage treatment plant was in the order of 2% of the total flow. Based on these volumes and the temperature measurements, a heat balance on the creek indicated a temperature increase of 0.4°F could be expected whereas an average increase of 2.8°F, as reported above, was measured. The reasons for this discrepancy are not known.

Wastes from the copper refinery and the decant from the tailings area were discharged to the south branch of Copper Cliff Creek, known as Finland Creek. The average temperature obtained for this flow was 69.0°F. It is possible that the temperature of this flow would also not decrease to the freezing temperature during the winter. However, verbal reports from people acquainted with the area and the highway fog reports indicate the formation of dense fog conditions has not been as prevalent in the area of Finland Creek as it has been further downstream in the vicinity of Copper Cliff Creek and Highway No. 17.

At both Canadian Industries Limited and The International Nickel Company cooling ponds were used, primarily to reduce the volume of process water required but, at the same time, eliminating the discharge of large amounts of heated water to the receiving watercourse after being used for cooling purposes

on a once-through basis. In all processing plants, water used for industrial purposes undergoes a heat gain simply by passing through heated buildings. This heat gain is retained until the water leaves the buildings as wastewater.

Conclusions

Based on the temperature data obtained on June 3, 4 and 5, 1968 the industrial waste effluents caused a definite temperature rise in the stream. An increase of 0.4°F was calculated but an increase of 2.8°F was measured. The volume of wastewater contributed by Canadian Industries Limited was relatively small and, therefore, did not have a significant effect on the stream temperature. The effluent from the Copper Cliff sewage treatment plant was cooler than the stream itself but did not appear to significantly lower the stream temperature except for a localized area immediately downstream of the discharge. During the winter months, the treated sewage would be expected to be warmer than the stream temperature, and since it contributes a significant volume of water to the creek, would contribute to a rise in stream temperature.

Flowing or open water in any watercourse gives rise, under the appropriate climatic conditions, to the formation of fog. The moisture content of the atmosphere in the vicinity of a watercourse would be expected to increase with an increase in stream temperature, thereby making the required climatic conditions easier to satisfy. Therefore, it would appear that to completely eliminate the possibility of fog generation due to unnatural conditions, it would be necessary to reduce the stream temperature to the freezing point.

The causes of the intermittent fog formations at Highway No. 17 when not occurring elsewhere appear to be two-fold:

1. the natural topography of the area including the proximity of the creek to the highway and the natural depression in the terrain in the vicinity of the creek and highway, and

2. water above the freezing point in Copper Cliff Creek during the winter.

The precise atmospheric and other conditions necessary for the creation of a fog blanket or patches on Highway No. 17 would be difficult or impossible to ascertain with the data available at this time. However, since fog does exist and increased water temperatures increase the probability of fog formation, the waste discharges to Copper Cliff Creek do contribute to the fog condition.

Possible Methods of Reducing the Formation of Fog Conditions

A number of approaches towards reducing the frequency of the fog conditions on Highway No. 17 present themselves:

- (1) Diversion of the smelter and sewage treatment plant effluents from Copper Cliff Creek to either the main tailings disposal area or to a point where the warm water would not give rise to similar conditions of fog near a street or highway. This may not entirely solve the problem since a major portion of the flow in Copper Cliff Creek is made up of tailings area decant. The temperature of this flow in the winter season is not known although it is known that its temperature during June was less than the temperature in the creek downstream of the smelter and sewage treatment plant discharges. As mentioned previously, the fog conditions do not appear to be as prevalent in that area of the creek upstream of the smelter and sewage plant discharges.
- (2) Culverting of the creek is another possible solution. This would involve culverting the creek for a distance of approximately one mile from the vicinity of the sewage treatment plant east to Kelly Lake Road. Any water vapour rising from the aeration section of the

sewage treatment plant would not be eliminated.

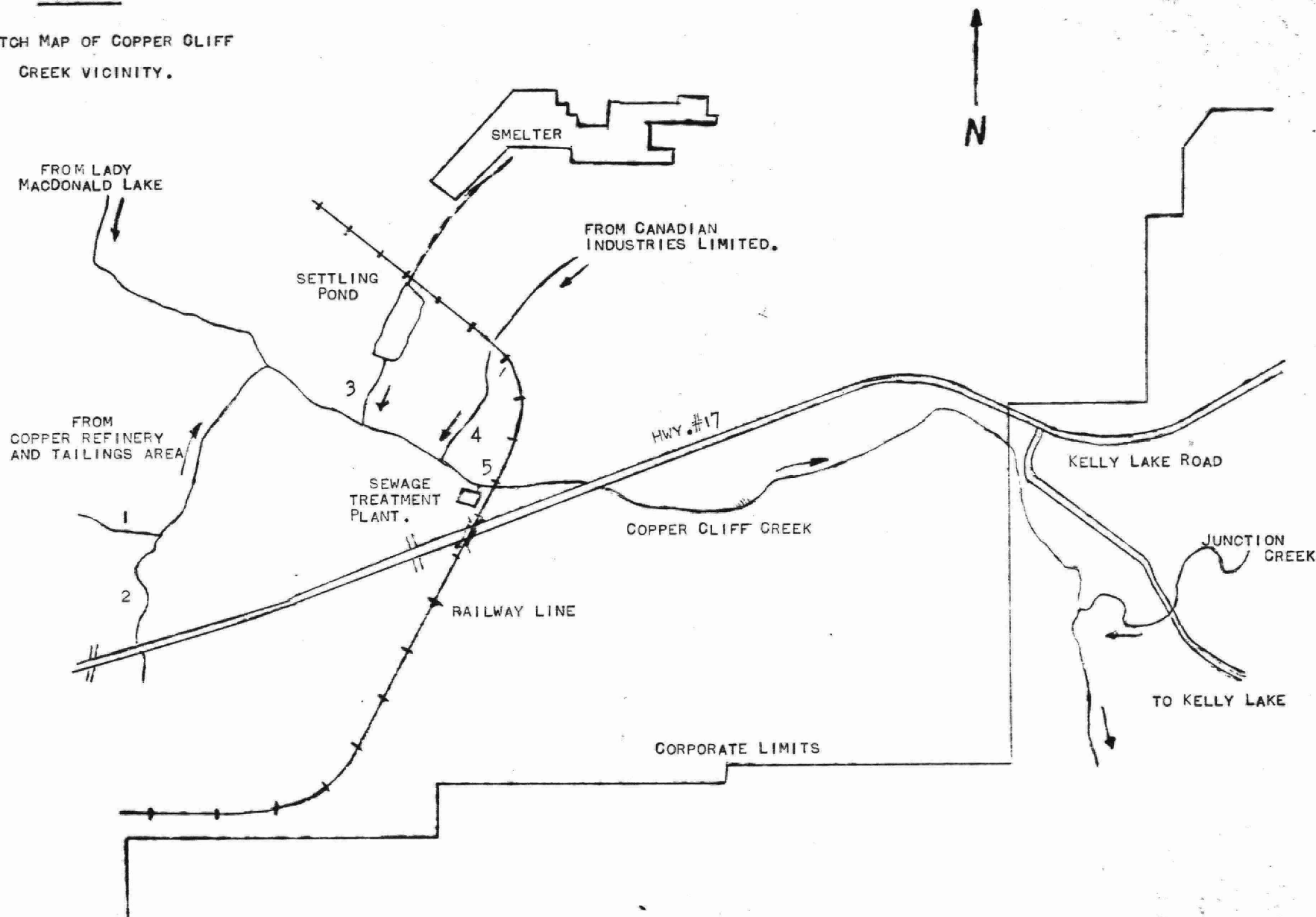
- (3) A partial solution could perhaps be achieved by cooling the wastes before discharge by means of cooling towers or ponds. The cooling effect of the existing pond during the winter is not known but in June, 1968, it was found to be only 1.5°F. A greater cooling effect would be expected during the winter when ambient temperatures are lower. However, it is felt that near-freezing temperatures would still not be attained by this method. An investigation conducted during the winter season would supply more information as to the degree of cooling that could be attained by this method. The sewage treatment plant effluent is not, at the present time, passed through a cooling pond.
- (4) A fourth approach, which may or may not be feasible depending on the topography of the area, involves reversing the flow in Copper Cliff Creek and directing it along the natural depression in the terrain west of the Iron Ore Recovery Plant to Kelly Lake.

RECOMMENDATION

It is recommended that a meeting between all parties having a concern in this matter be held at the earliest possible time. This would include the Ontario Water Resources Commission, Ontario Department of Health, Ontario Department of Highways, City of Sudbury, Town of Copper Cliff, the neighbouring townships, the Junction Creek Conservation Authority, INCO and C-I-L. The purpose of such a meeting would be to decide upon appropriate action to solve the problem. Attempts to determine responsibility should be considered only as being of a secondary nature.

FIGURE 1

SKETCH MAP OF COPPER CLIFF
CREEK VICINITY.



SCALE

4 INCHES = 1 MILE (APPROXIMATELY)

FIGURE 2

Air, dewpoint and
creek temperatures.

CCBS
MICROGRAPH

TEMPERATURE (°F)

GB-11
10 X 10 TO THE 1/2 INCH
MADE IN CANADA

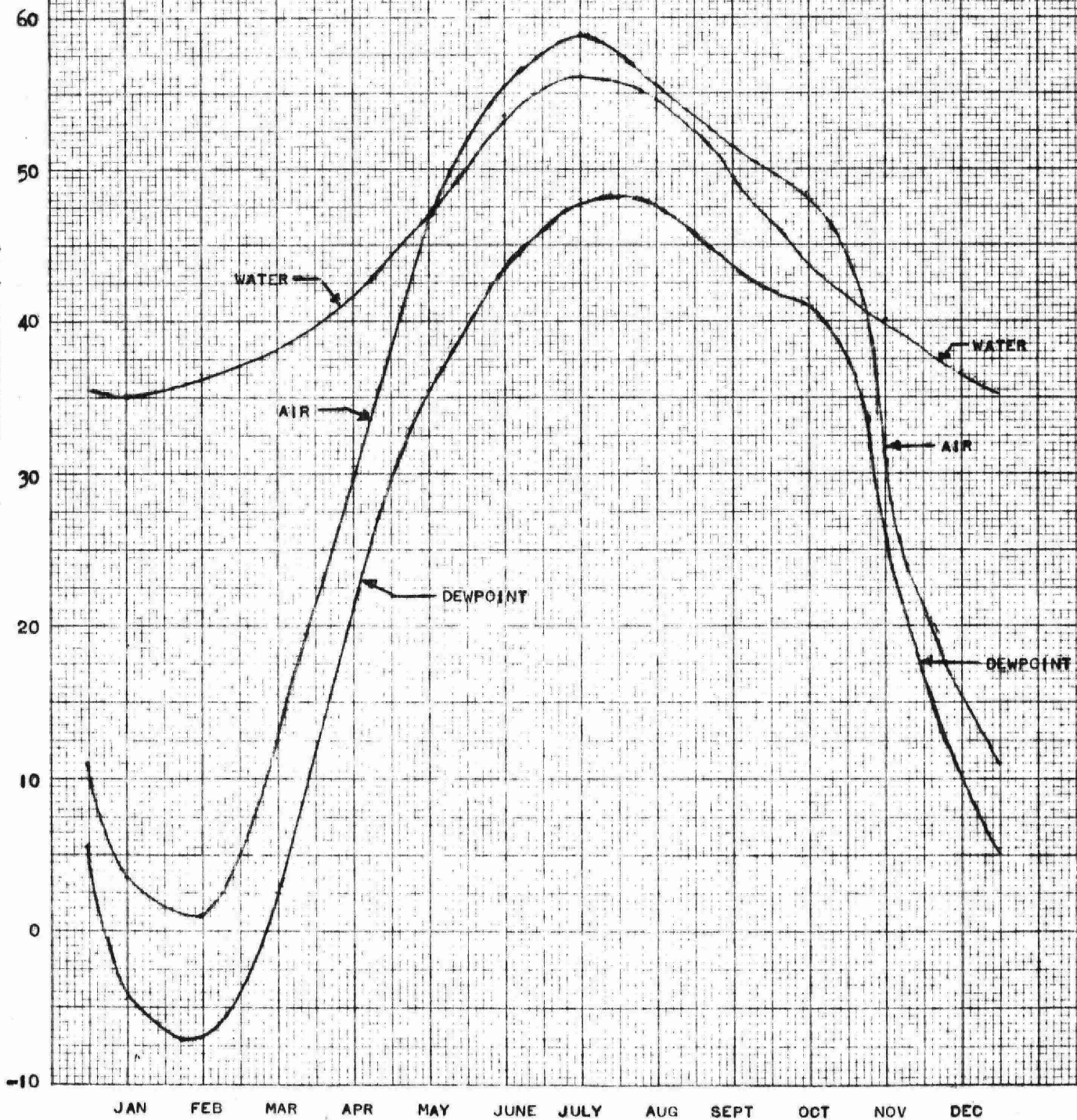


TABLE I

OCCURRENCE OF FOG CONDITIONS ON HIGHWAY NO. 17

(A) Winter Season of 1965-66

<u>Date</u>	<u>Time</u>	<u>Details</u>
20-12-65	0945	Fog patch at creek about 500 yards, visibility poor.
21-12-65	2200	Thick fog on 4 lanes up to Creighton turnoff, visibility poor.
24-12-65	-	Fog on all the patrol.
30-12-65	2100	Foggy all the way, visibility poor.
13- 1-66	2100	One fog patch east of lights at Power Street, 200 yards. One fog patch east of INCO overpass at creek, 200 yards. One at Cliffbury garage (Kelly Lake Road), 100 yards.
14- 1-66	0500	Light fog from Balsam Street (railroad overpass) to Cliffbury garage.
24- 1-66	0830	Fog on four lanes at creek for 300 yards, visibility nil.
26- 1-66	0845	One fog patch from Balsam Street about 800 feet, visibility nil. One patch at Cliffbury garage, 50 feet long, visibility poor. Rest of highway, visibility good.
29- 1-66	-	Fog on four lanes from 2015 to 2350.
4- 2-66	0240	Slight fog starting at 4 lanes for about 200 feet.
5- 2-66	2230	Fog on 4 lanes from Cliffbury garage to Balsam Street. Light fog patch at Power Street, visibility fair, rest of patrol - visibility good.
10- 2-66	2030	Heavy fog from city limits to Duhamel flats (about 1/2 mile west of Iron Ore Plant).

...continued

TABLE I (continued)

<u>Date</u>	<u>Time</u>	<u>Details</u>
27- 2-66	0900	Foggy on all the patrol.
4- 3-66	-	Light fog on all the patrol.
5- 3-66	-	Light fog.
12- 3-66	-	Some light fog patches.

(B) Winter Season of 1967-68

11- 9-67	-	Light fog near creek - little fog in other areas.
30-11-67	-	Light fog from creek.
27-12-67	-	Heavy fog from creek.
29-12-67	-	Moderately heavy fog from creek.
3- 1-68	-	Heavy fog from creek.
11- 1-68	-	Very heavy fog near creek.
12- 1-68	-	Very heavy fog near creek.

NOTE: The above instances include only those where fog occurred at the specific location near the creek and was not a general condition over the entire area - i.e., no fog occurred at most or all of the other observation sites which were located some distance west of the creek.

TABLE II

SUMMARY OF TRAFFIC ACCIDENTS

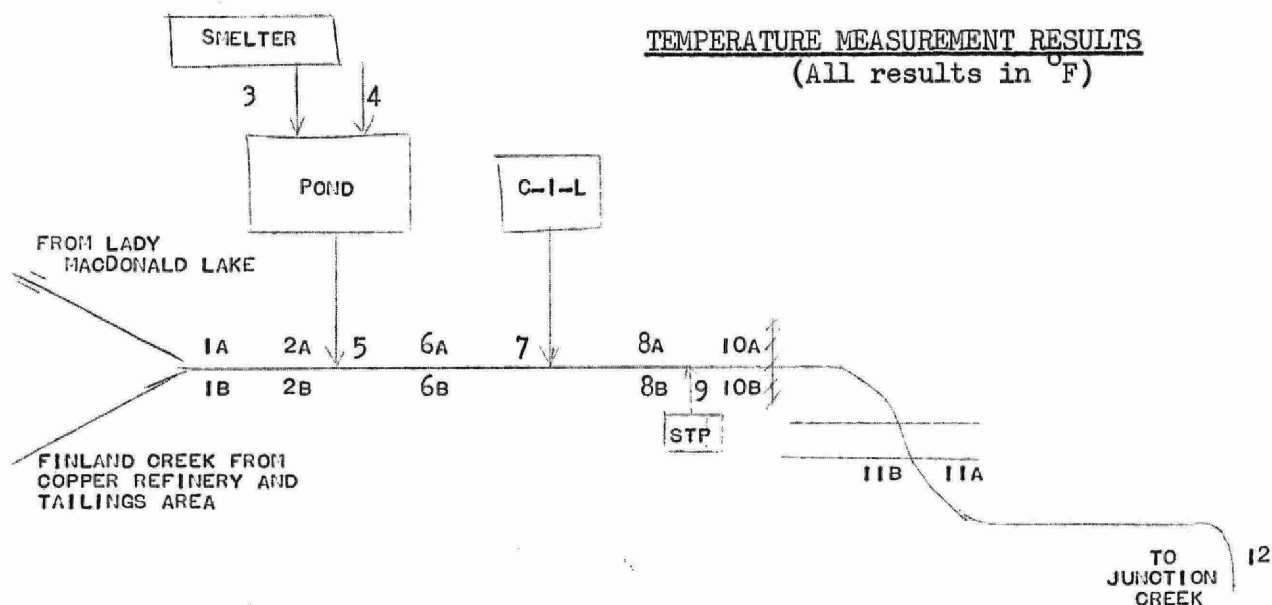
Highway No. 17 within limits of
Copper Cliff - 4 Lane Section

	<u>Total No. Accidents</u>	<u>No. Fatal Accidents</u>	<u>No. Accidents Involving Fog</u>
1963	16	1 - no fog	6 in December 1 in September
1964	34	1 - no fog	1 in January 1 in February 1 in August
1965	50	1 - no fog	3 in February 4 in December 1 in October
(lights installed December 21, 1965)			
1966	11	1 - no fog	nil*
1967	20	nil	nil
1968	23 to June 11	nil	6 on January 3 3 on January 12 1 in June

* Copies of reports at DHO show nil - Copper Cliff
Police said 2. (This information was obtained from
the Air Pollution Control Service of the Department
of Health and from the Department of Highways.)

TABLE III

TEMPERATURE MEASUREMENT RESULTS
(All results in °F)



(see following page for description of sampling points)

POINT	S A M P L I N G P E R I O D S								AVERAGE OF PERIODS 2 - 6
	1	2	3	4	5	6	7	8	
	JUNE 3 12:45 PM -1:45 PM	3:00 PM 4:40 PM	7:45 PM 9:20 PM	JUNE 4 9:20 AM 11:15 AM	2:50 PM 4:15 PM	7:55 PM 8:35 PM	12:00 MID	JUNE 5 6:45 AM 8:05 AM	
1A	-	66	66	64	74	73	-	66	68.6
1B	-	68	67	66	74	70	-	66	69.0
2A	64	67	66	64	74	71	67	66	68.4
2B	-	67	66	64	75	71	-	66	68.6
3	74	76	78.5	76	81	80	-	76	78.3
4	53	55	54	55	56	55	-	55	55
5	75	77	74	75	81	77	74	73	76.8
6A	64	72	70	70	78	74	-	70	72.8
6B	-	68	66	66	74	71	-	66	69.0
7	72	76	65	70	86	66	60	59	72.6
8A	68	70	68	69	78	73	-	68	71.6
8B	-	70	67	68	77	72	-	68	70.8
9	63	64	64	64	66	66	66	64	64.8
10A	69	70	67	69	78	73	-	68	71.4
10B	63	65	64	64	67	66.5	-	65.5	65.3

POINT	S A M P L I N G P E R I O D S								AVERAGE OF PERIODS 2 - 6
	1	2	3	4	5	6	7	8	
	JUNE 3 12:45 PM -1:45 PM	3:00 PM 4:40 PM	7:45 PM 9:20 PM	JUNE 4 9:20 AM 11:15 AM	2:50 PM 4:15 PM	7:55 PM 8:35 PM	12:00 MID	JUNE 5 6:45 AM 8:05 AM	
11A	69	70	68	70	77	72	69	68	71.4
11B	68	70	67	70	77	72	-	67.5	71.2
12	68	71	68	70	78	72	-	67	71.8
13	-	71	69	70	77	72	-	-	71.8
14	-	-	67	71	77	-	-	64	-
15	-	-	-	-	-	64	-	-	-
AIR TEMP.	68	-	75	71	76	67	-	63	-

<u>Sampling Point</u>	<u>Description</u>
1A	Copper Cliff Creek at Nickel and Balsam Streets (north side)
1B	Copper Cliff Creek at Nickel and Balsam Streets (south side)
2A	Copper Cliff Creek upstream of smelter settling pond discharge (north side)
2B	Copper Cliff Creek upstream of smelter settling pond discharge (south side)
3	Smelter wastewater discharge to settling pond
4	Groundwater seepage to settling pond
5	Settling pond discharge
6A	Copper Cliff Creek upstream of C-I-L discharge (north side)
6B	Copper Cliff Creek upstream of C-I-L discharge (south side)
7	C-I-L wastewater discharge
8A	Copper Cliff Creek upstream of sewage plant discharge (north side)
8B	Copper Cliff Creek upstream of sewage plant discharge (south side)
9	Sewage treatment plant discharge
10A	Copper Cliff Creek downstream of sewage plant discharge (north side)
10B	Copper Cliff Creek downstream of sewage plant discharge (south side)
11A	Copper Cliff Creek at Highway No. 17 (east side)
11B	Copper Cliff Creek at Highway No. 17 (west side)
12	Copper Cliff Creek at Kelly Lake Road (east side)
13	Copper Cliff Creek at Junction Creek
14	Lady MacDonald Lake
15	Vermillion River at Highway No. 17

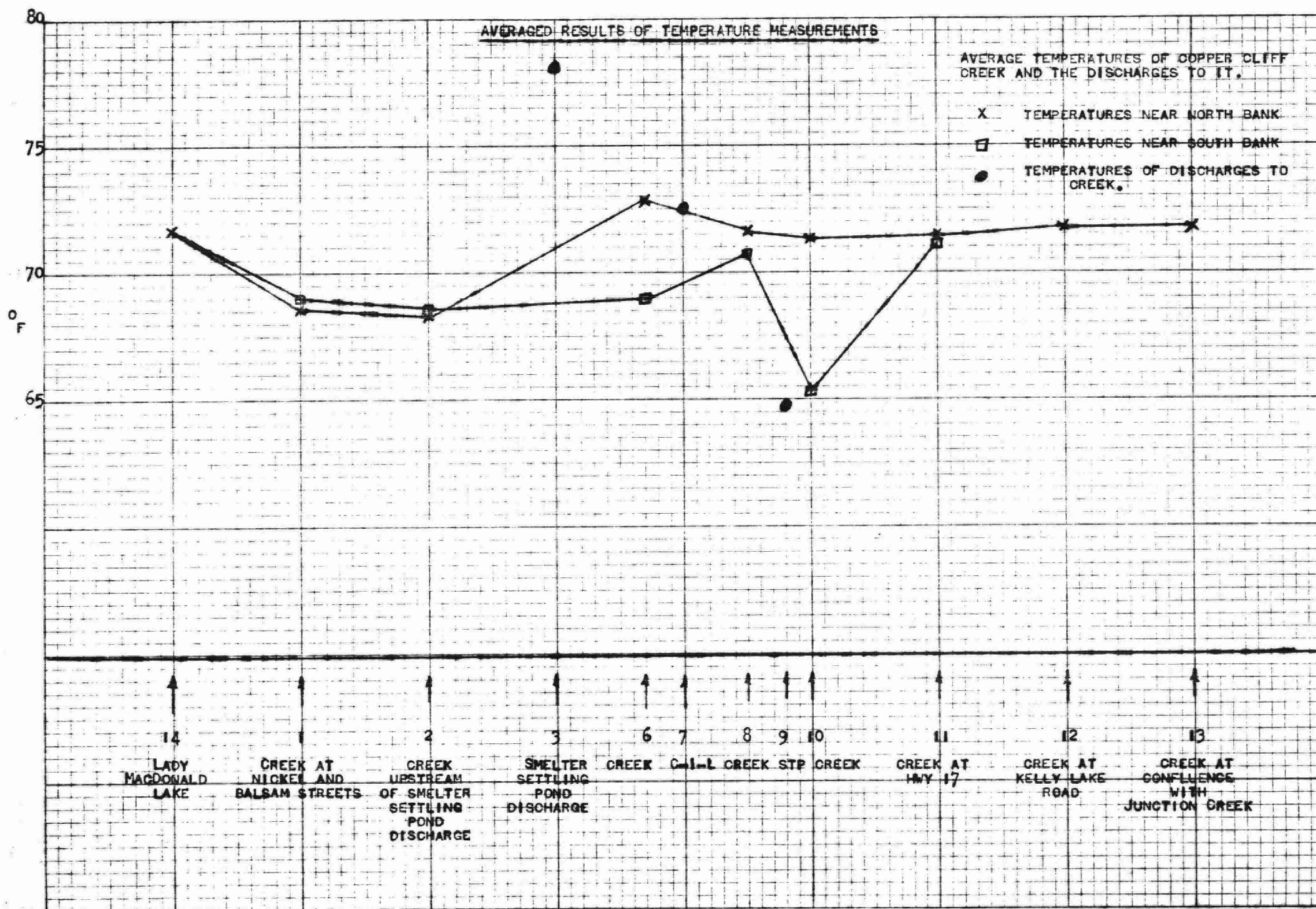


FIGURE 3

TABLE IV

CHEMICAL AND BIOCHEMICAL ANALYTICAL RESULTS

(All results in parts per million except pH)

Waste Stream	BOD ₅	Susp. Solids	Diss. Solids	pH	Copper as Cu	Nickel as Ni	Iron as Fe
Smelter Discharge	-	70-3170	1300- 2182	5.0- 11.9	0.1-28	0.1-8.3	0.1-17
C-I-L Discharge	-	7-250	500 - 860	2.6 - 6.5	3.6-29	0.1-20	18-75
Sewage Treatment Plant Discharge	4-47	30-46	414 - 600	6.0 - 7.1	0.2-2.2	1.2-3.5	-

TABLE V

FLOW DATA

Smelter discharge	- 2.2 MGD (obtained from company sources)
C-I-L discharge	- 0.05 MGD (obtained from company sources)
Sewage Treatment Plant Discharge	- 0.78 MGD (obtained from OWRC records)
Copper Cliff Creek	- 35 MGD (estimated from field observations)



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